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13. ABSTRACT *(Maximum 200 words)*

This award funded the purchase of a Digital Eye Tracking Research System (DETRS). The DETRS is a state-of-the-art system that allows cognitive scientists at Mississippi State University to integrate eye movement capture into their personnel optimization research. The DETRS enables integration of video and eye tracking data by capturing video data in a digital format, and allows access to several aspects of the same performance, such as pupil measures and point of gaze, and the ability to cross reference data from multiple subjects simultaneously. It includes high precision eye tracking instruments and components that enable the analysis and interpretation of the massive data sets. The non-linear digital data allows the selection of particular frames or crucial moments and this enables focused analysis and display of the data of interest. The DETRS is configured to maintain portability for field experiments and still provide the data storage and processing capacity necessary for archiving, editing and analyzing data. All equipment has been purchased, is in use, and is augmenting the research of multiple DoD and NSF grants.

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FINAL TECHNICAL REPORT

GRANT #: N00014-02-1-0619

PRINCIPAL INVESTIGATOR: Dr. Stephanie Doane (e-mail: sdoane@ra.psychology.msstate.edu)

INSTITUTION: Mississippi State University

GRANT TITLE: Integrating Digital Eye Tracking With Personnel Optimization Research

AWARD PERIOD: 1 April 2002 – 31 March 2003

OBJECTIVE:

Eye movements made during problem-solving, spatial thinking, and decision-making provide useful information about the processes by which people understand visual input and integrate it with their prior knowledge and memory during task performance (e.g., Just & Carpenter, 1993). Eye fixation studies provide a detailed account of the time course of processing, indicating the sequence of pupil fixations and the time the pupil dwells on each item fixated. Pupil size is also measured and used as an indication of cognitive workload (Just & Carpenter, 1993; Marshall et al., 1997).

Traditionally, cognitive science researchers have focused on two performance measures: reaction time and response accuracy. While such measures provide important information, their interpretation requires indirect inferences about subject focus of attention during task performance. In contrast, eye movement data provides real-time information about subject focus of attention during task performance. Recent cognitive science research integrates eye movements with traditional performance measures to study what humans attend to when they read text, comprehend diagrams, interact with computers, pilot aircraft, and perform other complex tasks (e.g., Doane & Sohn, 2000; Just & Carpenter, 1993; Lee & Anderson, 2001; Marshall et al., 1997). The addition of eye movement data eliminates any number of indirect inferences researchers must make when analyzing and interpreting human performance data. For example, a researcher observing reading skill who is limited to reading speed and comprehension measures may be unable to identify the locus of individual differences in performance. Integrating eye movements with the other performance measures allows the researcher to determine the reader's real-time visual focus and this information disambiguates the underlying causes of performance differences. Eye tracking is the technique researchers used to determine where their subjects were looking and pupil status (e.g., dilation) during task performance (e.g., reading a diagram, viewing a radar screen). While the technique appears straightforward, these measures are difficult to achieve and require high precision instruments as well as sophisticated data analysis and interpretation tools (e.g., Marshall, 1997; Salvucci & Anderson, 2001).

The objective of this award was to fund the purchase of a Digital Eye Tracking Research System (DETRS). DETRS is a state-of-the-art system that gives cognitive science researchers at Mississippi State University the capability to integrate eye movements into their personnel optimization research. The DETRS enables the seamless integration of eye tracking technology with Digital Video (DV) camcorders and Cassette Recorders (DVCR) by capturing video data in a digital format. It enables simultaneous access to several aspects of the same performance, such as pupil measures and point of gaze, and the ability to cross reference data from multiple subjects. The non-linear digital data allows the selection of particular frames or crucial moments and this enables focused analysis and display of the data of interest. The DETRS includes high-precision eye tracking instruments and components that enable the analysis and interpretation of the massive data sets. The DETRS is configured to maintain portability for field experiments and still provide the data storage and processing capacity necessary for archiving, editing, and analyzing data.

The DETRS provides the opportunity for faculty and students to gain experience in eye tracking research, where they learn how to 1) design and execute eyetracker experiments, 2) integrate digital video and eye movement data, 3) perform statistical analyses of eyetracker data, 4) integrate eyetracker data with other performance measures, 5) computationally model human eye movements and compare them to actual eye movements, and 6) write publications that make significant contributions to personnel optimization research.

APPROACH: The DETRS is used by both faculty and students in a shared facility housed in the Department of Psychology. The DETRS includes individual workstations housed in investigator labs, as well as servers located in a shared facility. In some cases, the DETRS workstations have replaced aging systems in the individual laboratories and, in so doing, provide the computational power necessary to perform state-of-the-art eye tracking research. The 2 eyetrackers are housed in the shared facility unless checked out for field research.

ACCOMPLISHMENTS: All of the DETRS equipment has arrived and is in use. A list of the purchased equipment is indicated in Table 1. Mississippi State University provided funds for laboratory remodeling necessary to house the DETRS. The remodeling was completed in July 2002. The remodeled rooms house the servers, oculometers, and workstations required to integrate eye-tracking technology into personnel optimization research. In addition, we have completed instructional documentation that facilitates the use of the DETRS equipment by faculty and students unfamiliar with eye tracking research.

CONCLUSIONS: The equipment purchased is enhancing or has enhanced the research and research-related education of seven personnel optimization research projects funded by the Office of Naval Research (N00014-02-1-0152, N00014-02-1-0898, N00014-00-1-0560, N00014-03-1-0088, N00014-02-1-0114, N00014-01-1-0093, N00014-01-1-0091) and a National Science Foundation grant (DUE 0089420) and supervised by investigators affiliated with the Applied Cognitive Science program at Mississippi State University.

SIGNIFICANCE: The DETRS provides the opportunity for faculty and students to gain experience in eye tracking research, where they will learn how to 1) design and execute eyetracker experiments, 2) integrate digital video and eye movement data, 3) perform statistical analyses of eyetracker data, 4) integrate eyetracker data with other performance measures, 5) computationally model human eye movements and compare them to actual eye movements, and 4) write publications that make significant contributions to personnel optimization research.

PATENT INFORMATION: No patents reported.

AWARD INFORMATION: Doane promoted to Professor, Department of Psychology, Mississippi State University.

REFEREED PUBLICATIONS (2002):

1. Doane, S. M., Sohn, Y. W., & Jodlowski, M. (in press). Pilot Ability to Anticipate the Consequences of Flight Actions as a Function of Expertise. *Human Factors*.

2. Sohn, Y.W., & Doane, S. M. (in press). Roles of Working Memory Capacity and Long-Term Working Memory Skill in Complex Task Performance. *Memory and Cognition*.

3. Cross, G.W., & Doane, S.M. (2002). Discriminating Among Meaningful Stimuli: Strategic Aspects of Visual Discrimination Skills. *Proceedings of the 46th Annual Meeting of the Human Factors Society* (pp. 2054-2058). Baltimore, MD.

4. Doane, S. M., & Carruth, D. W. (2002). *Tutoring Real-Time Dynamic Task Performance: Using ADAPT to Augment Pilot Skill Acquisition.* Short paper presented at the 24th Annual Meeting of the Cognitive Science Society (p. 36). Fairfax, VA.

5. Jodlowski, M. J., Doane, S. M., & Sohn, Y.W. (2002). Mental Models, Situation Models, and Expertise in Flight Situation Awareness. *Proceedings of the 46th Annual Meeting of the Human Factors Society* (pp. 377-381). Baltimore, MD.

6. Sohn, Y.W., & Doane, S.M. (2002). Evaluating Comprehension-Based User Models: Predicting Individual User Planning and Action. *User Modeling and User Adapted Interaction*, 12(2-3), 171-205.

7. Vickery, R. J., Keen, T. R., Moorhead, R. J., Brou, R. J., Carruth, D. W., & Doane, S. M. (2002). Volume Visualization of 5D Sedimentation Models. *Proceedings of Electronic Imaging Science & Technology Visualization and Data Analysis Conference*, R. F. Erbacher, P. C. Chen, M. Groehn, J. C. Roberts, and C. M. Wittenbrink, (Eds.) Proc. SPIE 4665, 12 pages, Jan 21-22, 2002, San Jose, CA.

BOOK CHAPTERS, SUBMISSIONS, ABSTRACTS AND OTHER PUBLICATIONS (2002):

1. Cross, G. W., Doane, S. M., Sohn, Y. W., Alderton, D. L., & Pringle, H. (Under review). *Strategic Aspects of Skill Transfer: Transfer of Strategies to Novel Stimuli.*

2. Cross, G. W., & Doane, S. M. (June, 2002). *Individual Differences in Strategic Skill Acquisition and Transfer*. Poster presented at the American Psychological Society Conference, June 6-9, New Orleans, LA.

3. Brou, R. J., Carruth, D. W., Doane, S. M., Vickery, R. J., & Moorhead, R. J. (August, 2002). *Effects of Disorientation on Human Spatial Cognition: Object Localization in Virtual Environments*. Poster presented at the 24th Annual Meeting of the Cognitive Science Society, August 7-10, Fairfax, VA.

4. Brou, R. J., Carruth, D. W., Doane, S. M., Vickery, R. J., & Moorhead, R. J. (September, 2002). Effects of Disorientation on Human Spatial Cognition: Object Localization in Virtual Environments. *Poster Proceedings of the 46th Annual Meeting of the Human Factors Society* (pp. 2184-2188). Baltimore, MD.

5. Doane, S. M., & Cross, G. W. (2002). *New Measures of Complex Visual Processing Abilities: Individual Differences in Strategic Learning and Performance. Invited* presentation at the Second Annual Navy Manpower, Personnel, and Training (MPT) Research and Analysis Conference, February 14-15, Washington, DC.

6. Brou, R. J., Carruth, D. W., & Doane, S. M. (Reviewed: revision in progress). Individual Differences in Object Localization in Virtual Environments. *Spatial Cognition and Computation.*

7. Doane, S. M., & Sohn, Y. W. (Reviewed: revision in progress). Predicting Pilot Visual Attention and Multiple Task Performance: Application of a Computational Theory of Cognition. *Journal of Experimental Psychology: Applied.*

8. Sohn, Y.W., & Doane, S. M. (Reviewed: invited resubmission in progress). Predicting Flight Situation Awareness Ability: Role of Individual Differences in Memory Processes. *Human Factors.*

9. Doane, S. M., Cross, G. W., & Sohn, Y. W. (in preparation). *The Role of Individual Differences in Spatial Ability in Strategic Skill Acquisition and Transfer.*

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1. Doane, S. M. & Sohn, Y. W. (2000). ADAPT: A Predictive Cognitive Model of User Visual Attention and Action Planning. *User Modeling and User-Adapted Interaction, 10(1),* 1-45.

2. Just, M. A., & Carpenter, P. A. (1993). The intensity dimension of thought: Pupillometric indices of sentence processing. *Canadian Journal of Experimental Psychology, 47,* 310-340.

3. Lee, F. J., & Anderson, J. R. (2001). Does learning a complex task have to be complex? A study in learning decomposition. *Cognitive Psychology, 42,* 267-316.

4. Marshall, S. P., Morrison, J. G., Allred, L. E., Gillikin, S., & McAllister, J. A. (1997). Eye tracking in tactical decision-making environments: Implementation and analysis. In *Proceedings of the 1997 Command and Control Research and Technology Symposium* (pp. 347-355). Washington, DC: National Defense University, ACTIS.

5. Salvucci, D. D., & Anderson, J. R. (2001). Automated eye-movement protocol analysis. *Human-Computer Interaction, 16,* 39-86.

Table 1. All equipment and software has been purchased and is in use. Following is a list of all equipment purchased by this grant and the purpose for each item:

Quantity	Data Integration Component	Purpose
1	Office X	Data processing and publication of research
4	Office for Dell Laptop/Desktop	Data processing and publication of research
2	Macromedia eLearning Studio Full Version	Writing programs to create computer tests and spatial cognition tests
1	Microsoft Visio Pro 2002	Building flowcharts and other visual aids to map software development paths and cognitive models
1	PhotoShop 7 Upgrade	Drawing and adapting figures for experiments and publication.
1	Portfolio 6.0	Organize images on hard drives by displaying thumbnails in the Finder
1	StuffIt Deluxe 6.5	File compression program for extracting files fro Internet archives
1	Apple Remote Desktop	Provide remote administration to Macs within the lab
1	Franz lisp	Programming in LISP for working with cognitive modeling architectures, ACT-R, and Construction-Integration to create cognitive models
2	Plextor Plex Writer	Burn CD backups of lab information and storage of data
1	G4	Prepare and program experiments, prepare stimulus materials, and analyze results
1	Apple Studio 17" Flat	Monitor for use with computers in research and publication
2	G4 Workstation	Integrate, analyze, and archive digital eye movement and video data
2	Apple Studio 17" Flat	Monitors for use with computers in research and publication
2	Apple Protection Plan for Power Mac	Warranties
1	G4 Media Center	Process video records of experiments, promotional video footage, and high-quality images for various projects.
1	Apple 22" Cinema Display	Part of media center
2	Apple Protection Plan for Power Mac	Warranties
1	Apple Pro Speakers	Part of media center
2	HP 8150DN	Provide hard copies of images for analysis and publication
2	512 K memory	Upgrade for Macs
1	Canon GL-2	Data collection in eye tracking and creating stimulus materials
2	Sony 19" Monitors	Use with G4s above
17	Dell Dimension 2200 (No Monitor)	Used for research-related education

Quantity	Furniture	Purpose
5	Workstation Desk	Workstations for computers and oculometers
2	Tables Lab	Workstations for computers and other equipment
3	Chairs	Used in lab for running subjects

Quantity	Eye Tracking Component	Purpose
3	Dell Precision 340	Run software that controls the ASL eye trackers and serve as experiment stations for the eye trackers.
2	Dell Latitude Laptop	Run software that controls the ASL eye trackers and serve as experiment stations for the eye trackers. Provide workstation mobility for field experiments
3	ASL Model 501	Record subject eye movements during task performance.
3	Eyehead Package	Record subject eye movements during task performance.
2	Upgrade 60Hz Camera	Upgrade cameras on eye trackers
2	Digital Video Camcorder	Record real-time scenarios and audio communications during task performance.
2	Hard drives for Dells	Replaced dysfunctional drives on 2 computers
1	Jeppesen JT201008 Instrument	Provide realistic interface to flight simulation software
1	PFC Cirrus Yoke	Provide realistic interface to flight simulation software
1	PFC Cirrus Rudders	Provide realistic interface to flight simulation software

Quantity	Data Analysis and Computational Modeling Component	Purpose
2	Sun V880 (4 processor)	Process data collected from pilots in simulated flight in real time – process oculometer data
4	Color Graphics Card	Video add-on to connect monitors to V880s
2	Sun Blade 100	Perform statistical evaluation of research data and computational modeling
2	Keyboard Kit	Part of purchased Suns
4	Sun monitors 21"	Part of purchased Suns
2	APC Smart UPS 2200	Backup power supply for servers
1	Netgear 5pt 10/100 Switch	Ethernet switch
1	Autoloader & Host Adapter	Automatically changes tapes during backup. Adapter allows V880 to communicate with autoloader

Quantity	Peripherals for equipment	Purpose
3	Sony LCM-PCA Carrying Case	Protects handicam units from physical shock damage and keeps them clean and dry
1	Y cable	Allows connection of flight yoke and foot pedals to same computer port.
4	APC Surge Station	Protect Dell computers against electrical surge
4	Kablit Security Package	Secure and protect new computers against theft
2	Snap-It Security Locks	Secure and protect new computers against theft